31 December 2002

Ms. Gloria Kulesa
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DOT Bldg
400 7th Street, SW
Washington DC 20590

Ms. Barbara Fuller
Department of Transportation
Federal Aviation Administration
William J. Hughes Technical Center
Office of Research and Technology Applications
Atlantic City International Airport, NJ 08405

Dear Ms. Kulesa and Ms. Fuller:

As per the requirements of FAA Grant # 2001-G-006 (An Objective System for Producing High-Frequency Guidance for Forecasting Aviation Sensitive Weather Parameters) that commenced on 9 January 2001, attached please find our final report.

Briefly, we successfully completed all of the major tasks planned for the first year of the project. Papers summarizing this work were presented this year at the AMS 10th Conference On Aviation, Range, and Aerospace Meteorology and at the AMS 19th Conference on Weather Analysis and Forecasting. This work has also been accepted for publication in the AMS refereed journals *Weather and Forecasting* and the *Journal of Applied Meteorology*. Despite several overtures to collaborate with the Ceiling and Visibility PDT, we were unable to work with them to produce a prototype operational software package for the baseline prediction systems that we developed. However, in addition to the ceiling and visibility work, we were able to develop a prototype system for short-term forecasting of thunderstorms. This work will be made available to the aviation community via formal publication.

Sincerely,

J. M. Fritsch

Final Report: FAA Grant # 2001-G-006

Date: 31 December 2002

Project Title: An Objective System for Producing High-Frequency Guidance for Forecasting Aviation-sensitive Weather Parameters

Institution: Department of Meteorology
503 Walker Building
Penn State University
University Park, PA 16802

Principal Investigator: J. M. Fritsch

1. Summary of Completed Project

The project consisted mainly of testing the hypotheses that increased surface observing density and observing frequency will improve the accuracy of current observations-based ceiling and visibility forecasting systems (See Appendix A). A supplemental effort to develop an observations-based system for providing short-term forecasts of thunderstorms was also undertaken.

a) *high-density observing system for forecasting ceiling and visibility*

An automated statistical system that utilizes regional high-density surface observations to forecast low ceiling and visibility events in the upper Midwest of the United States was developed and tested. The system is based solely upon surface observations as predictors, featuring forecast lead times of 1, 3 and 6 h.

A test of the forecast system on a five-year independent sample of events shows that for a 1-h lead time, an additional 2-4% reduction in the mean squared error (MSE) is obtained by the high-density forecasting system compared to that for a system utilizing only the standard synoptic observations. Tests on a 3-h lead-time reveal an additional 0-1.5% reduction in MSE by the high-density system over the synoptic system. Little improvement is gained by the high-density system at a 6-h lead-time.

b) *high-frequency observing system for forecasting ceiling and visibility*

An automated statistical system that utilizes regional hourly and high-frequency (inter-hour) surface observations to forecast low ceiling and visibility events in the New York City area was developed and tested. Forecasts feature lead times of 1 h and less.

Hourly forecast equations are developed with initialization times at the top of the hour as well as at 15, 30 and 45 minutes past the hour. Two forecasting systems were created; a baseline system that utilizes only hourly surface observations and an alternative system that utilizes both hourly surface observations and high-frequency observations. Introduction of the high-frequency observations into the forecasting system produces an additional 1.5-4.5% reduction in the mean squared error (MSE) compared to the baseline system for 1h forecasts made at the top of the hour. By 45 minutes past the hour, the reduction in MSE over the baseline system increases to 14-17%.

The high-frequency observations were also utilized to develop forecasts equations with lead times of 5 minutes to 55 minutes. Reduction in MSE for this rapid-update forecasting system compared to simple persistence increased from an average of 3% for a 5-minute lead time to an average of nearly 22% for a 55-minute lead time. Moreover, improvements over persistence climatology increased from an average of 1.5% for a five-minute lead time to an average of about 14% for a 55-minute lead time.

The results indicate that current observations-based forecasting techniques can be improved simply by utilizing higher density/frequency of surface weather observations. Thus, the uncertainty in decisions impacted by the arrival and duration of low ceiling and visibility can be reduced, thereby providing enhanced guidance for operational airport traffic delay programs.

c) *thunderstorm forecasting system*

An observations-based system that utilizes radar, surface, and upper-air data for forecasting thunderstorms in the 6-minute to 6-hour time period was developed and tested on the Norman, Oklahoma region. The main results from this study are summarized as follows:

- The observations-based system produced a 6-40% improvement (in mean-squared error) over persistence climatology through lead times of 360-min; performance was highest for the ultra-short-term lead times.
- Radar data have greatest contribution to skill for lead times ≤60 min, with an increasing contribution from surface mesonet, then upper-air, for longer lead times. By 360 min, the majority of predictors in the final forecast equations are from upper-air data.
- The upstream percent areal coverage of reflectivities above a given threshold is the most powerful predictor for all lead times; the optimal size for computing this parameter increases proportionally with lead time.

The results from this system suggest that a product such as this prototype would be of great utility and value to the commercial aviation industry in serving to optimize air-traffic flow during convective situations. The success of this system also suggests that similar statistical systems could be developed for other high-impact weather parameters, such as wind direction to optimize runway configurations. Technical details of the observations-based forecasting systems are available in the 1st and 2nd six-month reports and in the publications listed below.

2. Publications

a) *Refereed*

Leyton, S. M. and J. M. Fritsch, 2002: Short-term probabilistic forecasts of ceiling and visibility utilizing high-density surface weather observations. Accepted by *Wea. and Forecasting*.

Leyton, S. M. and J. M. Fritsch, 2002: The impact of high-frequency surface observations on short-term probabilistic forecasts of ceiling and visibility. Accepted by *J. Appl. Meteor.*

Hilliker, J. L. and J. M. Fritsch, 2002: An objective system for short-term probabilistic forecasts of thunderstorms. To be submitted to *Wea. and Forecasting*

Hilliker, J. L. and J. M. Fritsch, 2002: Quality control of radar, profiler, and mesonet data for a statistical forecast system. To be submitted to *Wea. and Forecasting*

Hilliker, J. L. and J. M. Fritsch, 2002: Sensitivity of a statistical forecast system to various observing platforms. To be submitted to *Wea. and Forecasting*

b) *Conference and Preprint Papers*

Hilliker, J. L. and J. M. Fritsch, 2001: A statistical system for short-term probabilistic forecasts of thunderstorms using high-resolution datasets. AMS Preprints, 18^{th} Conf. on Weather Analysis and Forecasting, 30 July-2 August, Ft. Lauderdale, FL, pp. 196-200.

Leyton, S. M. and J. M. Fritsch, 2002: Improved short-term probabilistic forecasts of ceiling and visibility. AMS Preprints, 10^{th} Conf. On Aviation, Range, and Aerospace Meteorology, 13-16 May, Portland, OR, pp. 146-149.

Leyton, S. M. and J. M. Fritsch, 2002: The use of high-frequency weather observations to improve short-term probabilistic forecasts of ceiling and visibility. AMS Preprints, 19^{th} Conf. on Weather Analysis and Forecasting/15^{th} Conference on Numerical Weather Prediction, 12-16 August, San Antonio, TX, pp. 108-111.

Appendix A: Statement of Work for Year 1

<u>Specific Tasking for PSU</u>: Year 1: January 1, 2001 – December 31, 2001

1.0 Identify observing sites and obtain data archive suitable for product development

1.1 Select site for one high spatial resolution of surface observing network and one high-frequency (20 minutes or better) network, preferably from the standard federal observing network. Selected sites must have a historical data archive of at least 3 years.

1.2 Acquire and Pre-Process Surface Data for at least 3 years for each identified site.

1.E1 Mar '01: List of Surface Observing Sites selected and data requirements identified.
1.E2 Jun '01: Data preprocessing complete.

2.0 Develop baseline predictive equations

2.1 Develop predictive equations for hourly forecasts at each of the selected observing sites using the hourly observations available.
2.2 Document baseline methodology to facilitate technical transfer to the C&V PDT.

2.E1 Jul '01: Baseline Prediction System complete.
2.E2 Sep '01: Deliver documentation of the baseline technology.

3.0 Develop and evaluate alternative predictive equations

3.1 Develop an hourly predictive system (I) utilizing the hourly observations from the spatially-enhanced observing network.
3.2 Develop an hourly predictive system (II) utilizing the high frequency observations from the temporally-enhanced observing network.
3.3 Develop a rapid-update (20 minute or better frequency) prediction system (III) utilizing the high frequency observations from the temporally-enhanced observing network.
3.4 Evaluate all forecasting systems on the training database, compared with the hourly benchmark systems.

3.E1 Sep '01: Hourly predictive system (I) complete.
3.E2 Nov '01: Hourly predictive system (II) complete.
3.E3 Dec '01: Hourly predictive system (III) complete.
3.E4 Dec '01: Report describing the three new prediction systems and their performance.

4.0 Collaborate with the Ceiling and Visibility PDT and the Aviation Weather Center to develop a prototype operational software package for the baseline prediction system

4.1 Provide assistance to the C&V PDT in constructing a prototype operational forecasting software package for the baseline prediction system.

4.E1 May '01: Status of efforts presented at either TIM and/or Collaboration/Status Meeting.
4.E2 Oct '01: Status of efforts presented at TIM and/or Collaboration/Status Meeting.
4.E3 Nov '01: Annual Report detailing Accomplishments to Date and Continuing Activities including results of Forecasting System Comparison.
4.E4 Dec '01: Baseline technology debrief.